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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE BOARD OF PATENT APPEALS
AND INTERFERENCES

Ex parte THEODORE I. KAMINS
and PHILIP J. KUEKES

Appeal 2009-001586
Application 10/690,688[1]
Technology Center 1700

Decided:[2] June 11, 2009

Before PETER F. KRATZ, MARK NAGUMO, and
KAREN M. HASTINGS, *Administrative Patent Judges*.

NAGUMO, *Administrative Patent Judge*.

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[1] Application 10/690,688, *Method of Forming Three-Dimensional Nanocrystal Array*, filed 21 October 2003, which is said to be a continuation-in-part of Application 10/281,678 filed 28 October 2002. The specification is referred to as the "688 Specification," and is cited as "Spec." The real party in interest is listed as Hewlett Packard Development Company, LP. (Appeal Brief, filed 30 October 2007 ("Br."), 3.)

[2] The two-month time period for filing an appeal or commencing a civil action, as recited in 37 C.F.R. § 1.304, begins to run from the Decided Date shown on this page of the decision. The time period does not run from the Mail Date (paper delivery) or Notification Date (electronic delivery).

DECISION ON APPEAL

A. Introduction

Theodore I. Kamins and Philip J. Kuekes ("Kamins") timely appeal under 35 U.S.C. § 134(a) from the final rejection[3] of claims 1, 5-24, and 28-40, which are all of the pending claims. We have jurisdiction under 35 U.S.C. § 6. We AFFIRM-IN-PART.

The subject matter on appeal relates to structures comprising nanowires comprised of two materials embedded in a matrix, and methods of making such structures, which are said to include quantum dots and photonic bandgap crystals. The record indicates that such materials are expected to have diverse practical applications in "nanotechnology," including nanoelectronics, optical communications, and sensors.

Representative Claim 1 is reproduced from the Claims Appendix to the Principal Brief on Appeal:

> 1. A method of controllably forming a three-dimensional assembly of isolated nanowires, each nanowire comprising at least two materials within a matrix of an other material, said method comprising:
>
> providing a substrate;
>
> forming a two-dimensional catalyst array on a major surface of said substrate;
>
> controllably growing in a third dimension an array of said nanowires corresponding with said catalyst array, said nanowires each comprising said at least two materials; and

[3] Office action mailed 30 May 2007 ("Final Rejection"; cited as "FR").

> forming the matrix of the other material that fills in spaces between said nanowires.

(Claims App., Br. 18; paragraphing and indentation added.)

The claims described briefly below are representative of the groups of claims that Kamins argues separately.

Claim 7 depends on claim 1 via claims 5 and 6, and requires: that the first and second materials that make up the nanowires be selected from the same closed list of materials; that the first and second materials differ from one another; and that the third material, which forms the matrix, can be the same or different from either the first or second material. Claim 7 specifies that the third material may also be selected from "oxides, nitrides, and oxynitrides." (Claims App., Br. 19.)

Independent claim 24, although not a product-by-process claim, covers assemblies corresponding to products made by processes covered by claims 1 and 5-7.

Independent claim 31 covers "[a] photonic bandgap structure comprising an assembly of isolated nanowire segments of a first material within a matrix of a second material." (Claims App., Br. 25.)

Independent claim 33, although not a product-by-process claim, covers a quantum dot structure corresponding to a structure made by the process of claim 1 in which the matrix material may be the same or different from the second material, but is different from the first material. (Claims App., Br. 26.)

Independent claim 15 covers processes similar to those covered by claim 1, but specifies that the nanowires are made of two materials that form alternating regions. (Claims App., Br. 21-22.)

Claims 8 and 19 depend from independent claims 1 and 15, respectively, and require that the step of forming the catalyst array comprise transferring catalyst from protrusions on a mold to a major surface of the substrate. (Claims App., Br. 19, 22-23.)

Claim 9 depends from claim 1 and requires that the step of forming the catalyst array comprises imprinting orthogonal lines of a material on a catalyst layer and removing catalyst material by etching so that catalyst remains only where protected by both imprints. (Claims App., Br. 19-20.)

The Examiner has maintained the following grounds of rejection:[4]

A. Claims 1, 5-7, 10-18, 20-24, and 28-40 stand rejected under 35 U.S.C. § 103(a) in view of the combined teachings of Li[5] and Gudiksen.[6]

B. Claims 8, 9, and 19 stand rejected under 35 U.S.C. § 103(a) in view of the combined teachings of Li and Gudiksen.

In brief, Kamins' principal objection (covering claims 1, 5, 6, 10-18, 20-24, 28, 29, 38, and 39) is that Li and Gudiksen are not combinable because the 700 V/cm electric field taught by Li for aligning nanowires

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[4] Examiner's Answer mailed 29 January 2008. ("Ans."). The Examiner withdrew a rejection for lack of written description. (Ans. 2.)

[5] Jun Li et al., *Catalyst Patterning for Nanowire Devices*, U.S. Patent 6,831,017 B1 (14 December 2004), based on an application filed 5 April 2002.

[6] Mark S. Gudiksen et al., *Growth of Nanowire Superlattice Structures for Nanoscale Photonics and Electronics*, 415 Nature 617 (7 February 2002).

would be too small by a factor of more than 1000 to align the 20-nm diameter two-component nanowires taught by Gudiksen. (Br. 9, relying in part on the Kamins Declaration[7]). Kamins argues further that using the 10^6 V/cm electric field necessary to align 20-nm diameter nanowires in Li's process would have been beyond the level of ordinary skill in the art. (*Id.* at 10.) Moreover, according to Kamins, the electric field alignment is critical to Li's method because Li does not teach growing vertically oriented nanowires from a properly oriented single crystal substrate. (Br. 9.)

The Examiner maintains that the growth of alternating two-component nanowires taught by Gudiksen is sufficiently similar to the growth of the semiconductor nanowires taught by Li that the ordinary worker would have been motivated to alternate the composition in the Li process. (FR 3, Ans 3-4.) The Kamins Declaration is not persuasive, in the Examiner's view, because it lacks "factual evidence to support the conclusions set forth." (Ans. 5.)

The critical issue with respect to the main body of claims argued by Kamins is whether Kamins has shown that there would have been no reasonable expectation of successfully growing two-component semiconductor nanotubes with a vertical orientation by the Li methods.

We shall set out the issues regarding the other separately argued claims in the Discussion section *infra*.

[7] Declaration Pursuant to 37 C.F.R. § 1.132, signed by Dr. Theodore I. Kamins on 25 August 2006, of record. ("Kamins Declaration.")

B. Findings of Fact ("FF")

Findings of fact throughout this Opinion are supported by a preponderance of the evidence of record.

The 688 Specification

1. According to the 688 Specification, the invention is "directed to the fabrication of a plurality of single material or segmented nanowires embedded in a matrix." (Spec. 2, ¶ [0003].)

2. The 688 Specification indicates that, conventionally, semiconductor nanowires are synthesized by metal-catalyzed techniques, including variations on the so-called vapor-liquid-solid ("VLS") synthesis, in which each wire grows from a single particle or liquid drop of gold or other metal by growth in a furnace from a high-temperature gas. (Spec. 2, ¶ [0004].)

3. Silicon nanowires grown by this technique are said to be single-crystalline, the diameter being controlled by the size of the catalytic particle. (Spec. 2, ¶ [0005].)

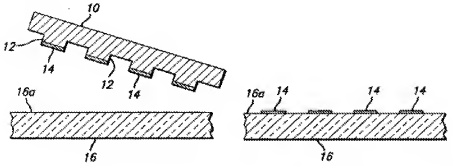
4. Creation and patterning of nanometer-sized catalyst particles is said to be non-trivial, but solved by the imprinting processes taught by the C-I-P parent application, 10/281,678. (Spec. 2, ¶¶ [0005 and 0006].)

5. According to the 688 Specification, useful catalysts include metals useful for catalyzing the growth of nanowires, such as gold. (Spec. 6, ¶ [0026].)

6. The 688 Specification teaches that gold is also a useful catalyst for growing germanium (Ge) nanowires. (Spec. 6-7, ¶ [0026].)

7. In the words of the 688 Specification, referring to Figures 1b and 1c,

{Figure 1b (left) and Figure 1c (right) are shown below :}



{Figures 1b and 1c are said to show transfer of a catalyst to a substrate}[8]

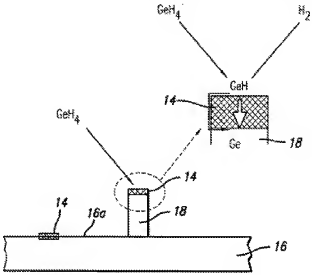
"[t]he substrate **16** may comprise *any* material having a noncatalytic surface **16a** capable of accepting the catalytic nanoparticles [**14**] transferred from the mold **10**." (Spec. 7, ¶ [0027]; emphasis added.)

8. As shown in Figures 1b and 1c, one method of transferring catalyst is to first coat a catalyst-containing material **14** on protrusions **12** of a mold **10**, and then to transfer the catalyst-containing material **14** by physical contact of the coated protrusions 12 with surface **16a** of a substrate **16**. (Spec. 6, ¶ [0024].)

9. Referring to Figure 2, which is reproduced on the following page, the 688 Specification teaches that germanium nanowires **18** are grown by introducing a gaseous source of germanium, such as germane (GeH_4), to the substrate bearing the catalyst particles. (Spec. 7, ¶ [0028]; emphasis added.)

[8] The text in curly braces following the Figures is provided to ensure compliance with § 508 of the U.S. Rehabilitation Act for publication of this Opinion on the USPTO website pursuant to the Freedom of Information Act. It is not part of the Opinion.

{Figure 2 (lower) and Figure 2a (upper) are shown below :}



{Figures 2 and 2a are said to show the growth process of a nanowire}

10. As shown in Figure 2a, germane is transformed on the catalyst **14** to germanium atoms, which diffuse through or around the catalyst to form the growing nanowire **18**: thus, the catalyst **14** remains on top of the nanowire. (Spec. 7, ¶ [0028].)

11. According to the 688 Specification, "it will be readily appreciated that by introducing one gas, e.g., germane, for a period of time and then switching to a second gas, e.g., silane (SiH_4) for a period of time and then switching back, it is possible to grow nanowires having alternating regions of the two compositions, Ge and Si." (Spec. 7, ¶ [0029].)

12. The 688 Specification teaches that the spaces between the nanowires can be filled by a third material (Spec. 8, ¶ [0033]), that may be selected on the basis of its optical or electrical properties (*id.* at ¶ [0034]).

13. Specific examples of the third material are said to include oxides such as silicon dioxide (SiO_2) and polymers such as polydimethylsiloxane. (Spec. 8, ¶ [0035].)

14. According to the 688 Specification, SiO_2 is a preferred material due to its transparency to ultraviolet radiation and consequent usefulness in photonic band gap applications. (Spec. 8-9, ¶ [0035].)

15. One ideal embodiment described as being useful as a photonic bandgap structure is said to comprise nanowires of alternating Ge and Si surrounded by a matrix of Si, wherein the substrate, matrix, and Si segments of the nanowire are each single crystal silicon, and the Ge segments are single crystal germanium. (Spec. 9, ¶ [0036].)

16. The 688 Specification instructs that a three dimensional structure with all dimensions less than a critical dimension (for Si and Ge, about 10 nm) is commonly called a "quantum dot." (Spec. 9, ¶ [0039].)

Li

17. Li describes ways to pattern catalyst sites from which nanowires are grown, as well as the resulting nanowire arrays (Li, col. 1, ll. 33-35), which may be provided with a layer of material to provide mechanical stability and electrical insulation (*Id.* at col. 2, ll. 5-10.)

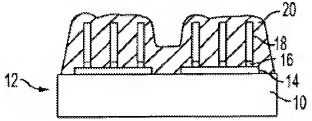
18. Li teaches further that the assemblies may be diced to provide a die having a portion of the nanowire structure formed on the substrate, which may be packaged and interconnected with circuitry and other devices. (Li, col. 2, ll. 11-15.)

19. Figure 2d, which is reproduced on the following page, illustrates the main features of the disclosed nanowire growth process.

20. Device **12** is formed using substrate **10**, which may be silicon or other wafers typically used in the semiconductor industry (Li, col. 3, ll. 62-66),

although "[a]ny suitable substrate material may be used if desired" (*id.* at col. 4, ll. 3-4).

{Li Figure 2d is shown below :}



{Figure 2d is said to show nanowires embedded in a matrix}

21. Li teaches that optional electrode pads **14** may be formed on substrate **10** to enable interconnects with nanowires and with circuitry on other devices. (Li, col. 4, ll. 9-12.)

22. Catalyst sites **16** may be provided on the pads where ever needed for a particular application. (Li, col. 4, ll. 52-55.)

23. Li teaches that the catalyst may be gold for catalyzing the growth of semiconductor nanowires. (Li, col. 7, ll. 8-10.)

24. According to Li, nanowire diameters are typically on the order of 10 nm to 100 nm, so the catalyst sites **16** typically have comparable lateral dimensions, "although sites with other suitable dimensions (e.g., 5-200 nm) may be used if desired." (Li, col. 4, ll. 59-63.)

25. Li teaches that "[n]anowires **18** may be grown using any suitable technique such as known thermal and plasma chemical vapor deposition (CVD) techniques." (Li, col. 5, ll. 10-12.)

26. In Li's words, "During plasma CVD growth, the inherent electric field produced by the plasma may help to vertically orient the nanowires **18** that are grown." (Li, col. 5, ll. 25-27; also see col. 6, ll. 20-28.)

27. According to Li, "[a] typical electric field strength that may be used to *enhance* nanowire alignment may be on the order of 700 V/cm." (Li, col. 5, ll. 30-32; emphasis added.)

28. Li does not teach that the electric field is necessary for forming vertically oriented nanowires.

29. Li teaches that after the nanowires have been grown, "an insulating layer such as a silicon oxide layer may be deposited or grown on the nanowires to form electrical insulation and to provide mechanical stability." (Li, col. 5, ll. 42-45.)

Gudiksen

30. Gudiksen describes the growth of "nanowire superlattices," i.e., nanowires formed from two different materials, such as gallium arsenide/gallium phosphide by laser assisted catalytic growth.

31. According to Gudiksen, "the nanowire axes [sic: axis] lies along the <111> direction, in agreement with previous studies of single component systems." (Gudiksen, 617, col. 2, first full paragraph.)

32. Gudiksen describes wires having diameters of about 20 nm, comparable to the ~20-nm diameter of the Au [gold] catalyst used. (Gudiksen, 617, col. 2, second full paragraph.)

33. Gudiksen indicates that nanowires having a diameter of about 5 nm could yield junctions with substantially reduced compositional variations, which would be particularly useful in photonic and electronic applications where abrupt interfaces are important. (Gudiksen, paragraph bridging 617-18.)

34. Gudiksen suggests that "[u]sing materials with a large dielectric contrast might also enable the creation of one–dimensional waveguides with built-in photonic bandgaps or of cavities for nanowire lasers." (Gudiksen, 619, col. 2.)

35. Gudiksen suggests further that "[b]y defining a quantum dot heterostructure within a p-n diode during nanowire synthesis, it should be possible to engineer an electrically driven single-photon source with well-defined polarization. (Gudiksen, 620, col. 1, 2d full paragraph.)

C. Discussion

As the Appellant, Kamins bears the procedural burden of showing harmful error in the Examiner's rejections. *See, e.g., In re Kahn*, 441 F.3d 977, 985-86 (Fed. Cir. 2006) ("On appeal to the Board, an applicant can overcome a rejection [under § 103] by showing insufficient evidence of *prima facie* obviousness") (citation and internal quote omitted). Arguments not timely filed have been waived. 37 C.F.R. § 41.37(c)(1)(vii), second sentence.

Claims 1, 5, 6, 10-18, 20-24, 28, 29, 38, and 39

Kamins principal challenge to the Examiner's rejection is, essentially, that Li is not enabled for vertical semiconductor wires having a diameter on the order of about 20 nm. Dr. Kamins testifies that the 700 V/cm field taught by Li is sufficient to align carbon nanotubes having a diameter of 1.4 nm. (Kamins Declaration 3, ¶ 15, citing Exhibit 1, Ural.[9]) Although

[9] Ant Ural et al., *Electric-Field-Aligned Growth of Single-Walled Carbon Nanotubes on Surfaces*, 81 Appl. Phys. Lett. 3464 (2002).

we have no reason to doubt this statement, we have not been placed in a position to make the further finding of fact that the electric field required to align a single-walled carbon nanotube, which is a cylinder a single atom thick, is substantially the same as that required to align a solid semiconductor wire. Nor have we been placed in a position to determine that Li's disclosure that a 700 V/cm field can be used to enhance semiconductor nanowire alignment is incorrect as applied to nanowires having diameters ranging from 10 to 100 μm. Our reviewing court has held that both the claimed and unclaimed disclosures of a patent are presumptively valid. *Amgen Inc. v. Hoechst Marion Roussel, Inc.*, 314 F.3d 1313, 1355 (Fed. Cir. 2003). ("[W]e hold a presumption arises that both the claimed and unclaimed disclosures in a prior art patent are enabled.") Thus, the burden is upon a party challenging the enablement of a patent to prove, by a preponderance of the evidence, that the disclosure is not enabling. Kamins has failed to come forward with credible evidence that Li's teachings regarding electric field alignment of 10 to 100 μm diameter nanowires would have been dismissed as incorrect by persons having ordinary skill in the art.

Dr. Kamins testifies further that "[t]he deflection of the nanowire in an electric field decreases as the inverse fourth power of the diameter." (Kamins Declaration 3, ¶ 15.) Dr. Kamins does not, however, provide any explanation of this statement, nor does he provide a citation to the technical literature. Although we find Dr. Kamins' professional credentials impressive, we are unable to credit this unsupported assertion. *Cf. Rohm and Haas Co. v. Brotech Corp.*, 127 F.3d 1089, 1092 (Fed. Cir. 1997) (nothing in the Federal Rules of Evidence or Federal Circuit jurisprudence

requires the fact finder to credit the unsupported assertions of an expert witness.) Moreover, both Li and Gudiksen indicate that nanowires ranging from diameters at least as small as 5 nm are contemplated. (Li, col. 4, l. 62; Gudiksen, paragraph bridging 617-18.) Even if Dr. Kamins' analysis is correct, it does not account for the smaller diameter semiconductor nanowires suggested by Li and Gudiksen.

Similarly, Kamins' arguments that Li is not enabled for electric field-free vertical growth of semiconductor nanowires because Li does not disclose the use of a single crystal substrate oriented to expose the (111) surface are unsupported by citations to credible evidence in the record. In this regard, we find it striking that the 688 Specification does not appear to disclose that a specially oriented single crystal substrate is necessary, or even desirable, for obtaining vertically oriented nanowires. On the contrary, the 688 Specification teaches that "[t]he substrate **16** may comprise *any* material having a non-catalytic surface **16a** capable of accepting the catalytic nanoparticles transferred from the mold **10**." (Spec. 7, ¶ [0027]; emphasis added.) In summary Kamins has not provided any credible reason to presume that the disclosed "any surface" is limited to single crystal (111) surfaces, nor has Kamins explained why the metal electrode surface provided by Li cannot accept a catalytic nanoparticle. Kamins' remarks concerning the oxide layer on the surfaces provided by Gudiksen appear to be founded on similar considerations. For the foregoing reasons, we decline to credit Kamins' arguments regarding the alleged necessity of a (111)-oriented single crystal substrate.

We conclude that Kamins has not demonstrated harmful error in the Examiner's determination that a person having ordinary skill in the art

would have expected that the structures taught by Li to be "grown using any suitable technique such as known thermal and plasma chemical vapor deposition (CVD) techniques" (Li, col. 5, ll. 10-12; FF 23), could also be grown via the same catalyst by alternately introducing different gas sources of semiconductors, as taught by Gudiksen.

Claims 7 and 30

Kamins argues that neither Li, which teaches amorphous matrix materials, nor Gudiksen, which does not teach any matrix materials, teach or suggest the materials recited for the matrix in claims 7 and 30, which are said to be materials that form a crystalline matrix. (Br. 12.) This argument is without merit, as Claims 7 and 30 recite that the matrix material may be, in addition to the materials recited for the nanowire segments, "oxides, nitrides, any oxynitrides." (Claims App., Br. 19.) The 688 Specification indicates that single crystal silicon is a preferred matrix (Spec. 9, ¶ [0036], but the matrix is not limited to single crystal materials. Indeed, the 688 Specification teaches that polydimethylsiloxane—a noncrystalline polymer—is a suitable matrix material. The Federal Circuit has repeatedly instructed that limitations from the specification are not to be read into the claims. *See, e.g., Phillips v. AWH Corp.*, 415 F.3d 1303, 1323 (Fed. Cir. 2005) (en banc). Accordingly, we conclude that Kamins has not shown harmful error in the Examiner's rejection of claims 7 and 30.

Claims 31, 32, and 40, and claims 33-37

Regarding claims 31, 32, and 40, which are drawn to a photonic bandgap structure, and claims 33-37, which are drawn to a quantum dot structure, Kamins "submits" that neither Li nor Gudiksen teaches or suggests

such structures. (Br. 13.) Kamins further submits, without elaboration, that such structures would not have been obvious in view of these references. (*Id.*)

We find Kamins' first submission to be contradicted by Gudiksen, which suggests that "[u]sing materials with a large dielectric contrast might also enable the creation of one–dimensional waveguides with built-in photonic bandgaps or of cavities for nanowire lasers." (Gudiksen, 619, col. 2.) Gudiksen suggests further that "[b]y defining a quantum dot heterostructure within a p-n diode during nanowire synthesis, it should be possible to engineer an electrically driven single-photon source with well-defined polarization. (Gudiksen, 620, col. 1, 2d full paragraph.) On the present record, it is clear that Gudiksen suggests both photonic bandgap structures and quantum dot structures, and that they were widely recognized targets of opportunity by those skilled in the relevant arts. Kamins' unexplained assertions of nonobviousness are not persuasive of harmful error in the Examiner's rejection of the claims to these structures.

Claims 8 and 19: Catalyst Transfer, and Claim 9, Catalyst Patterning

Kamins argues that the absorbing catalyst template taught by Li as being suitable for transferring catalyst ink to a substrate does not correspond to the material described for the mold recited in claims 8 and 19. The mold material, according to Kamins, is described in the 688 Specification, paragraphs 0024 and 0025, as being a relatively hard material that is coated with a material containing the desired catalyst. (Br. 14-15.) Thus, Kamins argues, "[t]he characteristics of the template of Li contradict the characteristics of the Appellants' mold," and the stated purpose of

transferring a catalyst would be destroyed if Li's template could not absorb. (*Id.* at 15.) Therefore, in Kamins' view, coating a mold, as recited in claims 8 and 19, would not have been an obvious variant of absorbing the catalyst, as taught by Li. (*Id.*)

The Examiner responds that "[a] mold is used to make sure that the catalyst is placed correctly and each time running the process, the same place giving a uniform product. Thus, it is within the skill of the art to use molds in order to increase the uniformity of the final product." (FR 5; Ans. 6-7)

Regarding the steps recited in claim 9 of imprinting two orthogonal lines on top of catalyst material and removing catalyst material so it remains only where it is protected by both imprints, Kamins argues that neither Li nor Gudiksen teaches or suggests such steps. (Br. 15-16.) Such a process is not, Kamins argues, the result of optimizing the lithographic and other methods by Li. (*Id.* at 16.)

The Examiner responds that "[a]ppellants have not given any evidence that this is not within the skill of the art," and that 'imprinting to place a material in a set place is within the skill of the art in order that one can reproduce the same array every time." (Ans. 7.)

The Examiner has not cited any part of Li or Gudiksen that teaches the particular steps recited in claims 8, 9, and 19. Nor has the Examiner offered any rationale for modifying any teachings of either reference other than "optimization" and the desirability of making reproducible patterns. Such generalizations may be useful for placing a particular explanation of obviousness in a larger context, but they do not satisfy the requirement of

"some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness. This requirement is as much rooted in the Administrative Procedure Act, which ensures due process and non-arbitrary decisionmaking, as it is in § 103." *In re Kahn*, 441 F.3d 977, 988 (Fed. Cir. 2006) (citations omitted) (*cited with approval*, *KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398, 418 (2007)). The Examiner has failed to come forward with credible evidence in support of the conclusion of obviousness. We decline to scour the record in search of such evidence and evaluate whether that evidence outweighs evidence of nonobviousness. Our principal function is review, not examination in the first instance.

Accordingly, we REVERSE the rejection of claims 8, 9, and 19.

D. Order

We AFFIRM the rejection of claims 1, 5-7, 10-18, 20-24, and 28-40 under 35 U.S.C. § 103(a) in view of the combined teachings of Li and Gudiksen.

We REVERSE the rejection of claims 8, 9, and 19 under 35 U.S.C. § 103(a) in view of the combined teachings of Li and Gudiksen.

No time period for taking any subsequent action in connection with this appeal may be extended under 37 C.F.R. § 1.136(a).

AFFIRMED-IN-PART

tc

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